AGU Chapman
19-22 Feb 2012, Kona HI
SWT-2

Near Real-Time Global Satellite Monitoring of Flooding Events

Daniel A Slayback[1,2], G. Robert Brakenridge[3], Frederick S. Policelli[4], , Maura M. Tokay[1,4], Albert Kettner[3]
[1]Science Systems & Applications, Inc., [2]Biospheric Sciences Laboratory, NASA Goddard Space Flight Center, Greenbelt MD, [3]CSDMS, INSTAAR, University of Colorado, [4]Office of Applied Sciences, Earth Science Division, NASA Goddard Space Flight Center.

Motivation

Flooding is among the most destructive, frequent, and costly disasters (natural or otherwise) faced by modern society. Each year, several major, and often unprecedented, flooding events occur globally. In 2011, these events included: 100 year (and by some reports, 500 year) floods resulting from Hurricane Irene in the northeastern US; major flooding along the Mississippi; the Chao Phraya in Thailand, inundating parts of Bangkok; the Indus in Pakistan; coastal Japan after the tsunami; events in Cambodia, China, Colombia, Mozambique, and the Philippines, among others. The death and financial toll of these events has been substantial.

Flooding constitutes a significant percentage of disasters globally. Figures 1-3, from the Center for Research on the Epidemiology of Disasters (CRED[1]) show: (1) that floods are the most common natural disaster, accounting for over 30% of all reported natural disasters; (2) they are increasing in number, especially over the last 15 years; and (3) they are globally widespread.

Fig 1:

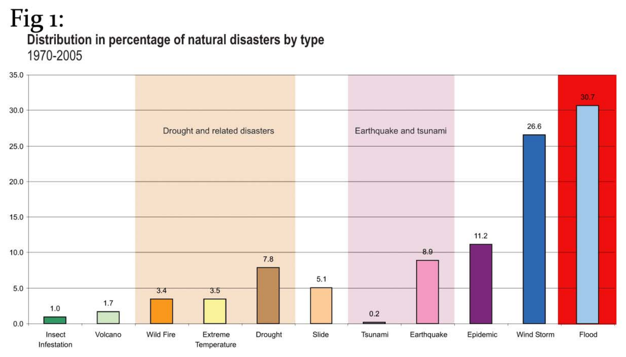


Fig 2:

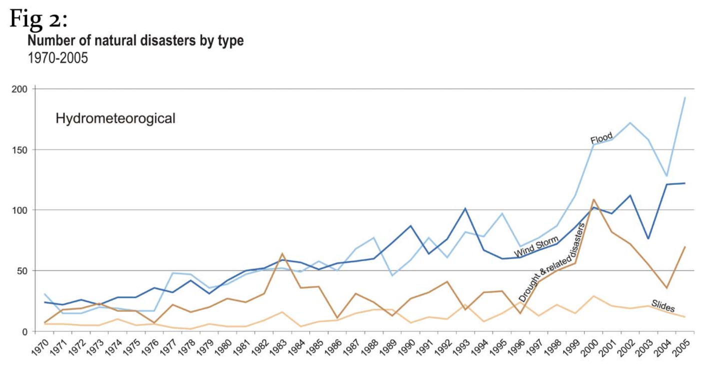
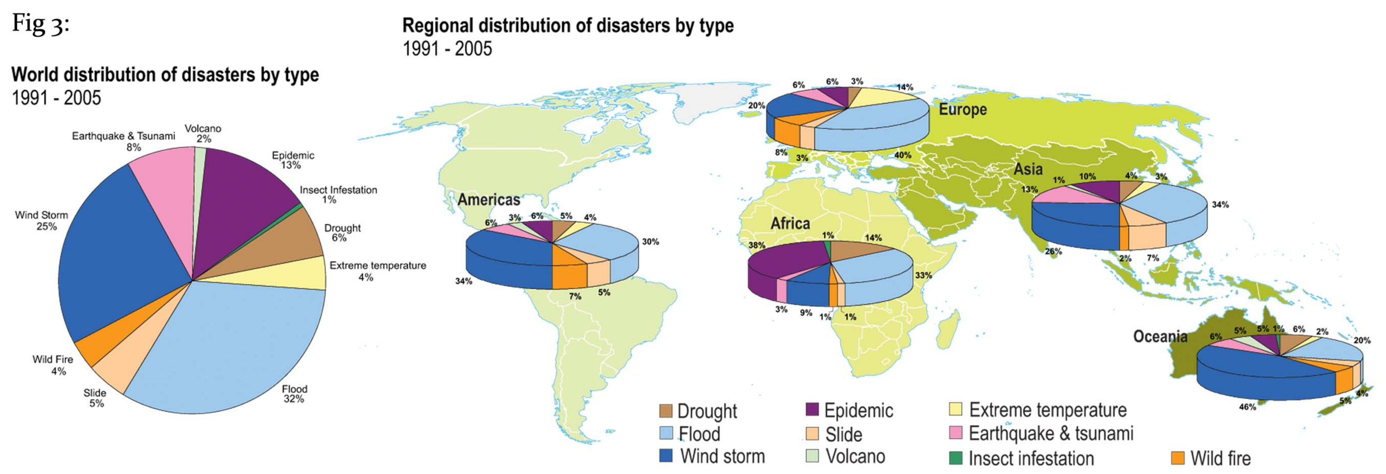
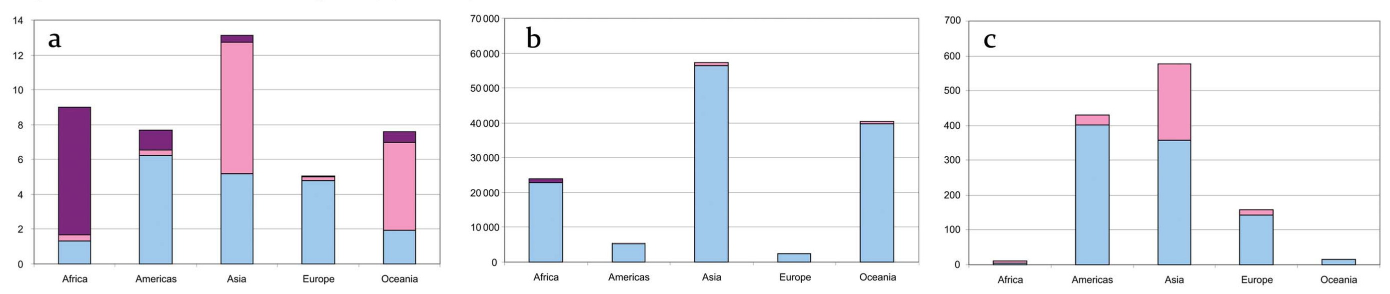


Fig 3:



The human and economic impact of flooding is substantial. As CRED reports, the majority of global disaster impacts, including numbers of people killed and affected, and economic damages, result from flooding:

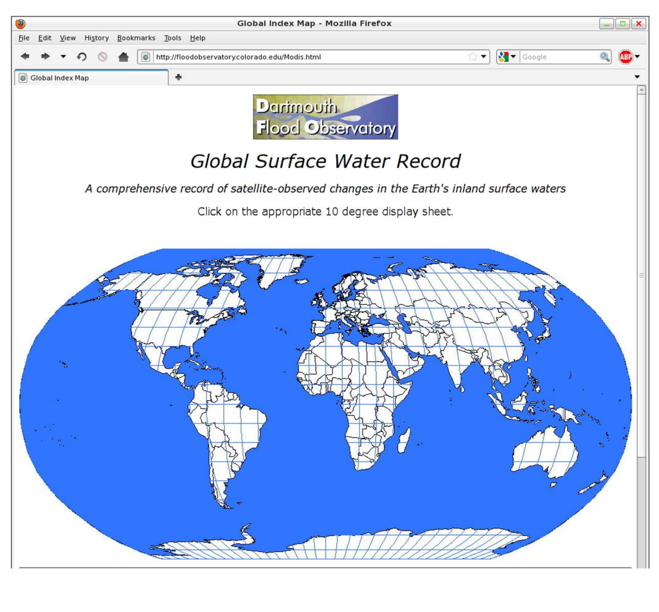
Fig 4: Average number people reported (a) killed and (b) affected, per million inhabitants, 1991-2005, and total reported economic damages, 1991-2005, billion US$. Hydrometeorological Geological Biological



An International Flood Initiative report (ICWHRM 2007[2]) estimates even higher impacts, with floods affecting greater than 520 million people per year worldwide -- one tenth of the global population -- and causing extensive homelessness, disaster-induced disease, crop and livestock damage, famine, and other serious harm. They estimate an annual death toll of 25,000, and an economic toll (including costs for other water-related disease) of $50-60 billion.

Unfortunately, disaster management agencies in many parts of the world have very limited capabilities to monitor the onset and progress of these events. Aid agencies such as the International Federation of Red Cross and Red Crescent Societies (IFRC) and government agencies such as FEMA (Federal Emergency Management Agency) and the Pacific Disaster Center are increasingly seeking better information concerning flooding extent in order to respond to and help mitigate the effects of damaging floods.

The Dartmouth Flood Observatory (original developed at Dartmouth College, but now housed at the University of Colorado) has developed algorithms for detecting flood water using daily imagery from NASA's MODIS satellite, and has been providing the resulting current floodwater information on freely available maps for the past decade (http://floodobservatory.colorado.edu/Modis.html).



However, the preparation of these flood maps has been a manual process, and so they are not always available in the timely manner needed by relief agencies at the start of an event, a particularly important time as the extent of flooding will be least understood.

To achieve near real-time flood map production, NASA's Applied Sciences Program provided funding to automate this process.

Our team has now operationalized global near real-time flood mapping from MODIS imagery.

References

1 http://www.emdat.be/isdr-trends, http://www.unisdr.org/disaster-statistics/occurrence-trends-century.htm

2 International Centre for Water Hazard and Risk Management (ICWHRM). 2007. International Flood Initiative: UNESCO, WMO, UNU, ISDR. UNESCO. http://www.unesco.org/ulis/cgi-bin/ulis.pl?catno=155652&set=4D024A84_2_52&gp=1&lin=1&ll=1.

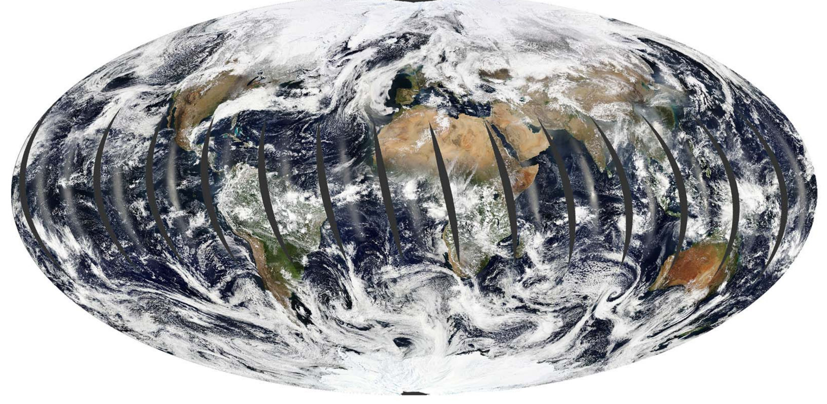
Approach

Key features:

1. Custom MODIS input imagery from the near real-time LANCE system at NASA Goddard.
2. Flood detection algorithm provided by B. Brakenridge/Dartmouth Flood Observatory.
3. Near real-time flood map production system developed at NASA Goddard.
4. Fully automated system runs 24/7, ingesting new MODIS imagery as available from LANCE, and delivering products on completion via web and ftp.
5. Daily products available within ~6 hours of Aqua overpass (~ 8:00 PM local time).

Input MODIS imagery

NASA's MODIS instrument (—>) images the earth once daily from each of two polar-orbiting satellites: Terra (morning overpass) and Aqua (afternoon overpass). It provides 250 m resolution optical imagery in a 2000 km wide swath, in two reflectance bands that are well suited for surface water discrimination. It thus provides a unique asset for daily, relatively high resolution earth imaging.



This image shows a daily composite for Aqua from March 19, 2009. The equatorial gaps between swaths are not fixed in space, but nevertheless result in some areas only being imaged by one spacecraft, on some days.

We engaged NASA's LANCE-MODIS system (Land Atmosphere Near real-time Capability for EOS, http://lance.nasa.gov) to provide us with custom imagery products, to ease the routine processing burden on our end. The LANCE system delivers a single daily image of calibrated band 1, 2, and 7 reflectances from each satellite, compositing all orbits for the day into 10-degree tiles. They also provide the corresponding cloud mask and solar angle products.

Flood detection algorithm

Key components:

1. Use empirically derived band ratio threshold to detect surface water: (Band1+A)/(Band2+B).
2. Combine multiple MODIS images to overcome issues with incomplete coverage (cloud, MODIS swath coverage gaps), and problematic cloud and terrain shadows (which often incorrectly appear as 'water').
3. Compare detected surface water to expected surface water (lakes, rivers, ocean) to produce flood water layer.

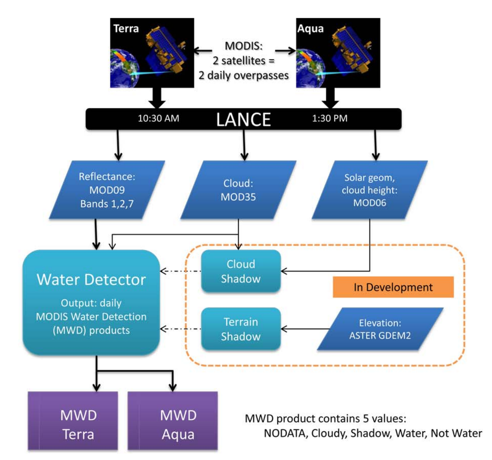
Near Real-Time Processing System

Product type:

MWD: MODIS Water Detection. Indicates water from single MODIS image only.

MSW: MODIS Surface Water. Water composited from several MWD products.

MFW: MODIS Flood Water. MSW with reference water removed to isolate floods.

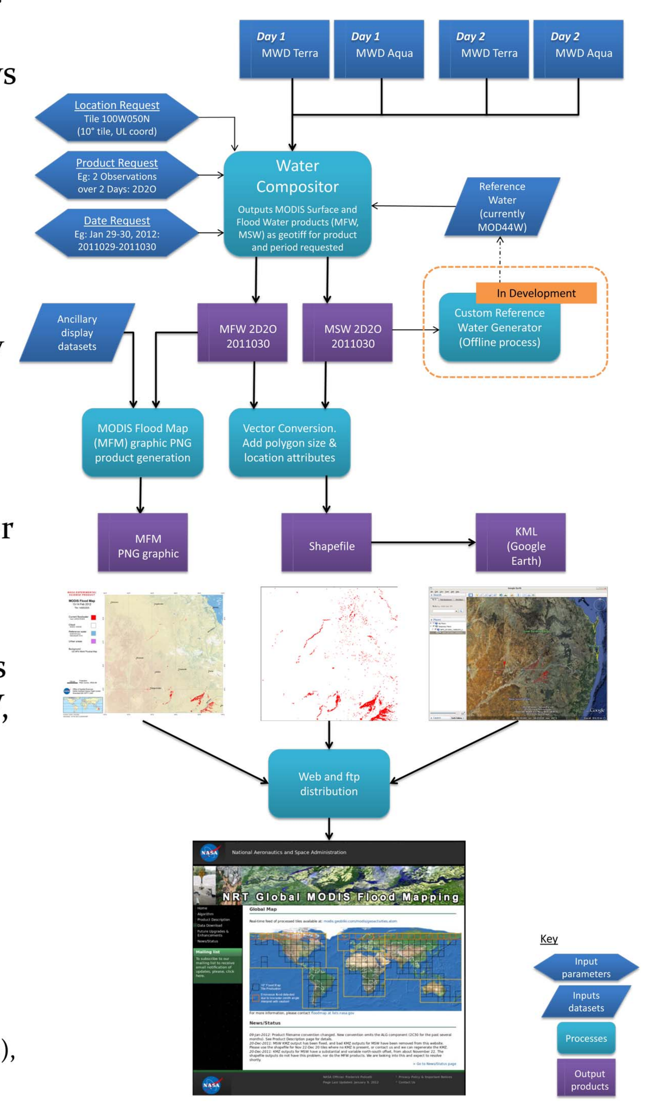


Product indicator: *XDYO*

Y gives the number of water observations required to tag a pixel as water, over the number of days given by *X*. The default product is 2D2O: 2 water observations required over 2 days of imagery. Requiring multiple days reduces gaps in coverage due to clouds; requiring multiple observations reduces false-detects due to shadows; both, however, increase product latency.

Key steps:

1. Water Detector module generates MWD base products, indicating detected water for each daily Terra & Aqua image.
2. Water Compositor module combines MWD files over the product-specified number of days, and outputs pixels as water when the required number of water observations has been met, generating the MODIS Surface Water (MSW) product.
3. Reference water (eg., expected normal water levels for rivers/lakes/ocean) is removed from the MSW, to produce flood (MFW) product.
4. Raster MSW and MFW products converted to shapefile and KML vector products.
5. Attributes for the size and centroid of each flood polygon included in vector products.
6. Graphic map display of each 10° map tile created.
7. Products posted to web (http://oas.gsfc.nasa.gov/floodmap), ftp'ed to alternate distribution sites (currently DFO), and announced via atom feed (http://modis.geobliki.com/modis/geoactivities.atom).



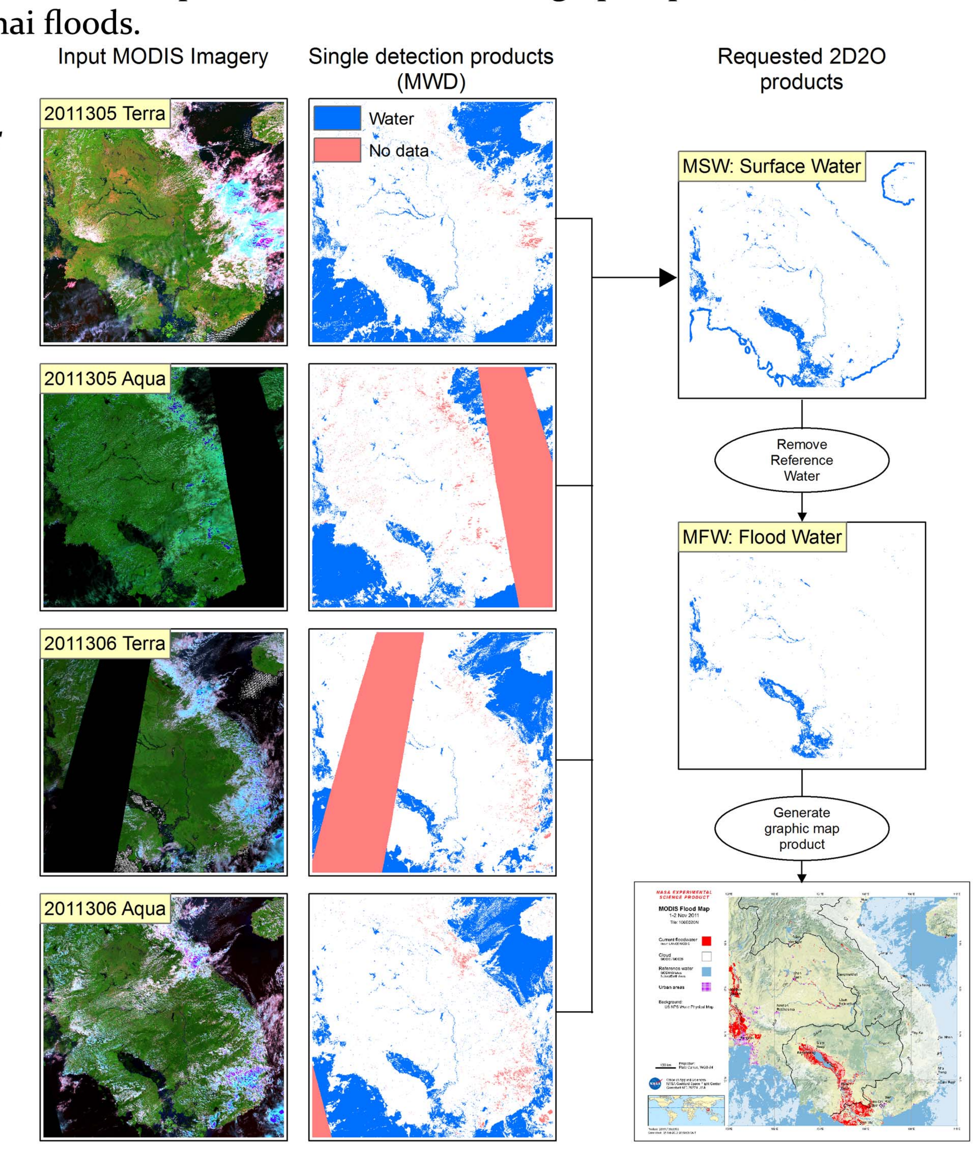
Results

The following figure shows the process from input MODIS reflectance imagery, to single-image MWD products, and to final composited MFW, MSW, and graphic products, for the 10° tile covering the late 2011 Thai floods.

Note that the MWD products have gaps in water detection where clouds occur; they are thus not reliable indicators of flood extent until composited over several days to have comprehensive cloud free imagery.

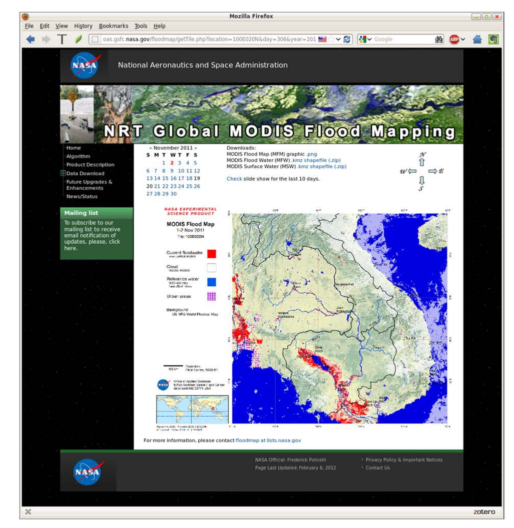
In this example, Tonle Sap lake in Cambodia also shows extensive flooding; however, this is, to some extent, the normal yearly expansion of the lake.

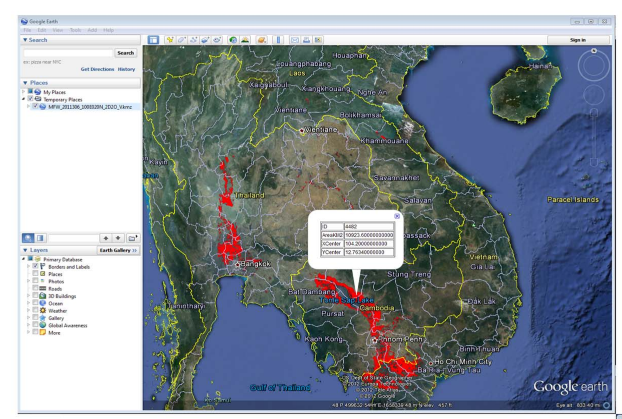
When we have implemented a custom reference water layer, we will be able to produce flood products that exclude such expected flooding.



Product Delivery

OAS website allows browsing archive of flood products. -->

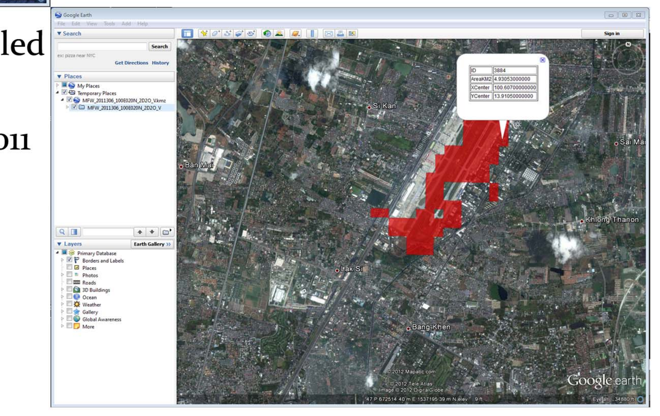




Shapefile & KML products allow detailed exploration and custom display.

Above: Thai flood overview, 01-Nov-2011

Right: Flooded runways at Bangkok's Don Muang Airport, 01-Nov-2011.



Latency

Satellite overpass --> LANCE product available: 3-6 hours.

LANCE --> Flood Map Product delivery: 30 minutes.

Total: 4-7 hours after Aqua overpass; typically products are available early evening local time.

Known Issues

- Cloud & Terrain shadows often get tagged as water without explicit screening; corrections underway.
- Dense vegetation: the system will not accurately detect flooding if water is not visible in 250m MODIS imagery. No simple fix.
- 250 m resolution daily data may not be sufficient for detecting small floods, floods in constrained and narrow valleys, or floods that do not persist for multiple days.

Next Steps

- Implement terrain & cloud shadow corrections, to create more useable single-image water detection products.
- Validation and accuracy assessment.
- Build webGIS interface for more flexible web-based product display.
- Test using VIIRS imagery; build modules to ingest routinely.
- Transition system to an operational partner; currently discussions are underway with the Pacific Disaster Center (http://www.pdc.org).
- Add capacity to include water detections from additional imagery resources, including various radar and Landsat.
- Explore automated triggering of hi-resolution satellite data acquisitions based on observed events.
- Investigate extrapolating flood waters under canopy, using high quality digital elevation models.